LA-UR-16-22121

Title: Possible path for the calculation of the fine structure constant

Author(s): Lestone, John Paul

Intended for: Seminar in Oppenheimer Library, LANL, 2016-03-30 (Los Alamos, New Mexico, United States)

Issued: 2016-04-04 (rev.1)

Possible path for the calculation of the fine structure constant

J. P. Lestone
XCP-3

Seminar in Oppenheimer Library, LANL
March 30th 2016

I hope you brought your towels

Feed back from my previous audience of March 17th is greatly appreciated

LA-UR-16-22121

The fine structure constant

The force between two charged leptons, or the force between a proton and a charged lepton is $F = \pm \frac{\alpha \hbar c}{d^2}$

$$\alpha^{-1} = 137.0359991$$

"… all good theoretical physicists put this number up on their wall and worry about it. … It's one of the greatest damn mysteries of physics…"
— Richard Feynman, QED: The Strange Theory of Light and Matter

"The theoretical determination of the fine structure constant is certainly the most important of the unsolved problems of modern physics. ... To reach it, we shall, presumably, have to pay with further revolutionary changes of the fundamental concepts of physics ..."
— Wolfgang Pauli, Writings on Physics and Philosophy

$r_C = \frac{\hbar c}{mc^2}$ Reduced Compton wavelength.
The reduced wavelength of the "light" if all a particle's mass is converted into a single photon

$$r_C(\text{electron}) = 3.87\times10^{-13}\text{ m}$$

$$r_B(\text{hydrogen}) = r_C(\text{electron})/\alpha = 3.87\times10^{-13}\text{ m} \times 137 = 0.53\times10^{-10}\text{ m}$$

$$E_B(\text{hydrogen}) = 0.5mc^2\ \alpha^2 = 511\times10^3\text{ eV} / 137^2 / 2 = 13.6\text{ eV}$$

$$v(\text{hydrogen}) = \alpha c = c/137,\ \ \langle\text{TKE}\rangle\ (\text{electron, hydrogen}) = 13.6\text{ eV}$$

$$r_e = \alpha r_C = 2.82\times10^{-15}\text{ m}$$

$$\sigma_C \sim \pi\,(\alpha r_C)^2 = 25\text{ fm}^2 \qquad \times\frac{8}{3} = 66.5\text{ fm}^2 = 0.665\text{ b}$$

Introduction to my idea

Before Hawking's work (and others) black-holes were believed to be point objects with only mass, spin, and charge. This is why Einstein (1930s) and others have previously considered the possibility that fundamental particles (like leptons) are quantum micro black holes. Black holes are now believed to have a temperature, entropy, and thus many internal degrees of freedom. Individual black holes are objects amenable to statistical mechanics.

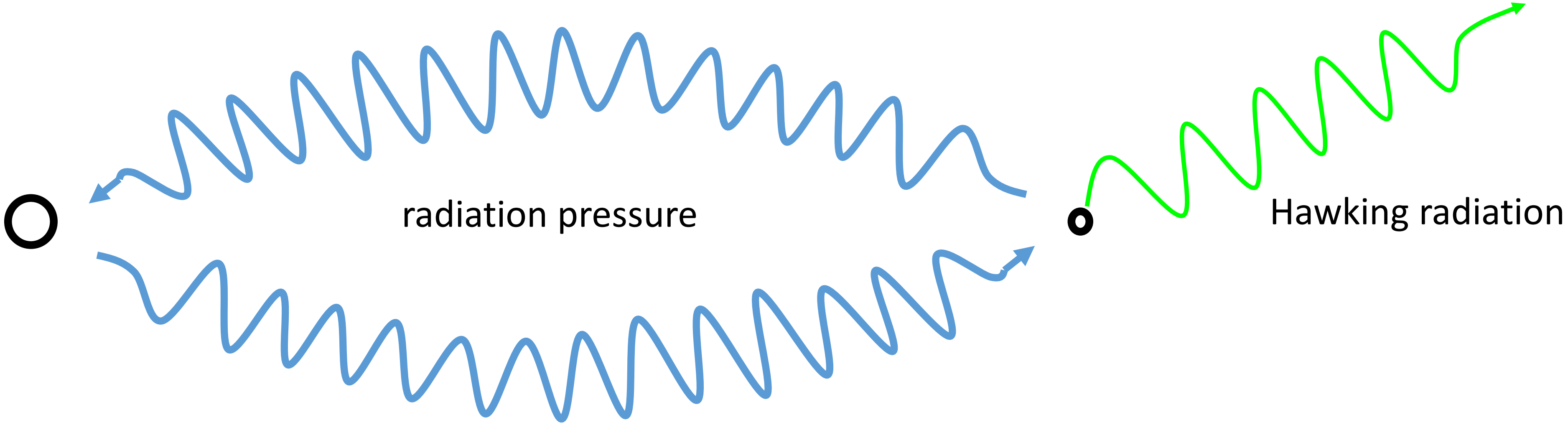
My heretical statement

If black holes (once thought to be point objects) are amenable to statistical mechanics, then why not fundamental particles like leptons? (1988)

Introduction to my idea continued

I consider the possibility of a very strange "unknown" imaginary class of particle, with several unique (bizarre) properties including

(1) My particles have a very high temperature(s).
(2) Despite having a high temperature, my imaginary particles can not change their rest mass upon the emission of electromagnetic energy. Using known physics my imaginary particles (if isolated) can not emit any "real" photons.
(3) However, I consider the possibility that my imaginary particles can emit and absorb unphysical *L*=0 "virtual" photons via the time-energy uncertainty principle.
(4) The emission and absorption is controlled by statistical arguments involving their classical temperature and possibly other effective temperatures.
(5) The emission and absorption between pairs, to 0th order, is controlled by a cross section $\sigma_a(\lambdabar, d) = \pi \lambdabar^2 \,\mathrm{erf}^2(d/(\lambdabar\sqrt{2}))$.
(6) The characteristic energy of the photons exchanged between particle pairs is given by $T_{ex}=\hbar c/(2d)$ and is assumed to define a Planckian exchange temperature.



The repulsive force generated by the exchange of “virtual” photons between my imaginary particles can be calculated. Its key properties are :

(1) It’s finite and inversely proportional to the separation distance, *d*, of the two particles;
(2) is independent of the mass, size, and temperature of both particles; and
(3) defines an effective charge of q=1.591×10^{-19} C, i.e 0.993 of the universal charge of 1.602177 ×10^{-19} C;
(4) with the reduced wavelength of the exchanging virtual photons ~*d*.

(7) If speculative QED-like corrections based on the anomalous magnetic moment of the electron are added then the model calculated effective charge is q=1.602177×10^{-19} C, with α^{-1}=137.0359.

$$F = \frac{q^2}{4\pi\varepsilon_0 d^2} \qquad q = d\sqrt{F 4\pi\varepsilon_0}$$

$$\alpha = \frac{q^2}{4\pi\varepsilon_0 \hbar c}$$

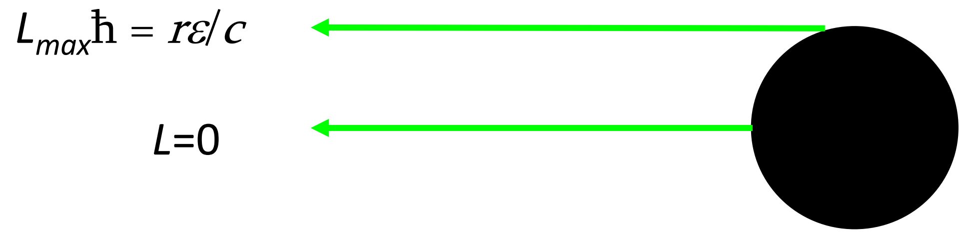
$$F = \frac{\alpha\hbar c}{d^2} \qquad \alpha = \frac{Fd^2}{\hbar c}$$

After I show the calculation of the force between my imaginary particles, I will add some additional assumed properties that enable them to have a magnetic moment of μ=1.00116 μ_B, if they were to be bound to a heavy particle of the opposite charge would have a Lamb shift of 1056 MHz, scatter photons with a cross section of 8πr^2/3, and annihilate with their anti-particles with a cross section of $\pi r^2 c/v$.

The Force between two radiating large classical black-body spheres

Decay width for black-body radiation from a hot sphere using transition state theory is

$$\Gamma = \frac{1}{2\pi}\int_0^\infty \sum_{\text{helicity}} \sum_{L=0}^{\infty} (2L+1) T_L(\varepsilon) \exp(-\varepsilon/T) d\varepsilon \qquad R = \frac{\Gamma}{\hbar}$$



Classical object $T_L(\varepsilon)=1$ if $L \le L_{max}$
$T_L(\varepsilon)=0$ if $L > L_{max}$

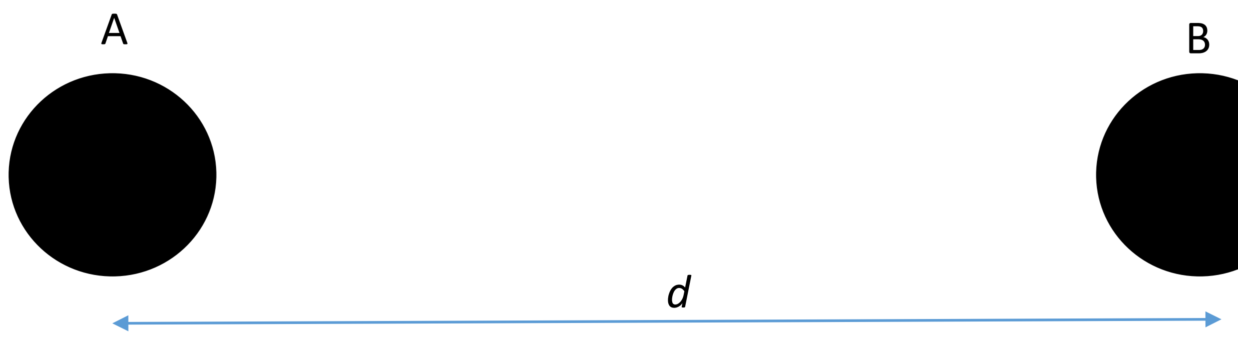
$$\Gamma = \frac{1}{\pi}\int_0^\infty \left(\frac{r\varepsilon}{\hbar c}\right)^2 \exp(-\varepsilon/T)\, d\varepsilon = \frac{4\pi r^2}{4\pi^2\hbar^2 c^2}\int_0^\infty \varepsilon^2 \exp(-\varepsilon/T)\, d\varepsilon = \frac{4\sigma_a}{4\pi^2\hbar^2 c^2}\int_0^\infty \varepsilon^2 \exp(-\varepsilon/T)\, d\varepsilon$$

$$P = \frac{4\sigma_a}{4\pi^2\hbar^3 c^2}\int_0^\infty \varepsilon^3 \exp(-\varepsilon/T)\, d\varepsilon$$

This expression only represents the spontaneous emission and does not include the effect of stimulated emission. For a perfect black body, stimulated emission can be included by replacing $\exp(-\varepsilon/T)$ with the Planckian factor $1/(\exp(\varepsilon/T)-1)$.
This also leads to a semi-classical picture of the HBT effect, see Lestone MPLA (2008).

$$P = \frac{4\sigma_a}{4\pi^2\hbar^3 c^2}\int_0^\infty \frac{\varepsilon^3}{\exp(\varepsilon/T)-1} d\varepsilon = \frac{4\sigma_a}{4\pi^2\hbar^3 c^2}\frac{\pi^4}{15} = 4\sigma_{\text{a}}\sigma_{\text{SB}}T^4 = A\sigma_{\text{SB}}T^4 \qquad \sigma_{\text{SB}} = \frac{\pi^2}{60\hbar^3 c^2}$$

This is the power of Hawking radiation from a large black hole with temperature $T_{bh}=\hbar c/(4\pi r_S)$.



$$P_{A\to B} = 4\sigma_{\mathrm{a}}\,\sigma_{\mathrm{SB}} T^4 \,\frac{\sigma_{\mathrm{a}}}{4\pi d^2}$$

$$F_{\mathrm{B}} = \frac{\sigma_{\mathrm{SB}} T^4}{c}\frac{\sigma_a^2}{\pi d^2} = \frac{\pi^2}{60\hbar^3 c^2}\frac{T^4}{c}\frac{\pi^2 r^4}{\pi d^2} = \frac{T^4 \pi^3 r^4}{60\hbar^4 c^4}\frac{\hbar c}{d^2} \qquad \alpha = \frac{T^4 r^4 \pi^3}{60\hbar^4 c^4}$$

$$T = 400\,K = 5.52\times 10^{-21}\ \mathrm{J} \qquad \alpha = 5\times 10^{20} \qquad q = \sqrt{\alpha 4\pi\varepsilon_0 \hbar c} = 4\times 10^{-8}\ \mathrm{C}$$

$$r = 1\ \mathrm{m}$$

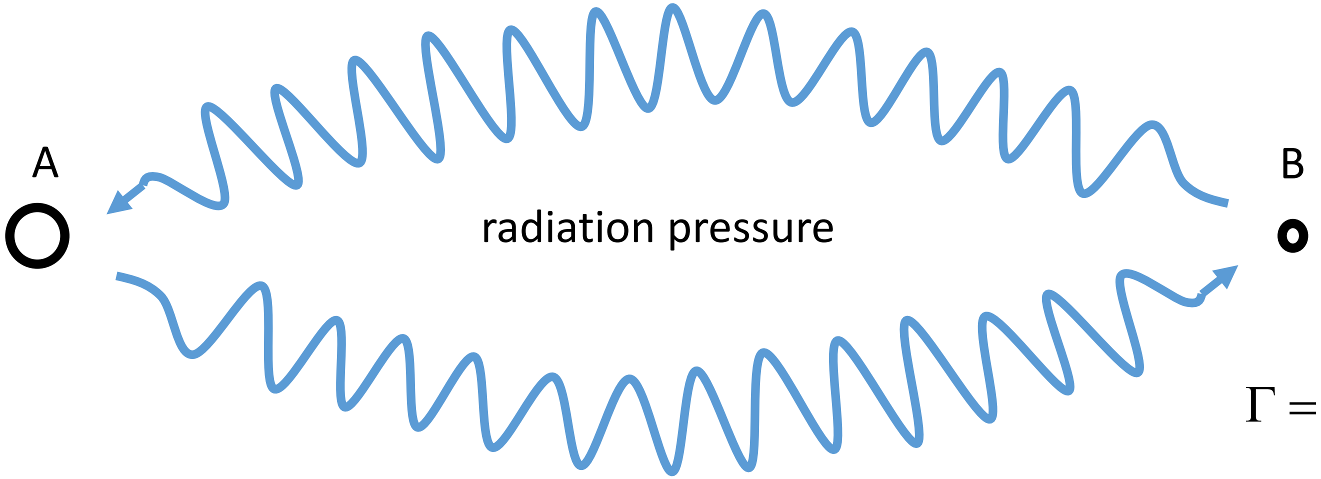
For black holes $r_a^2 = 6.75\cdot r_{\mathrm{S}}^2$ (geometrical optics) $\qquad T_{\mathrm{bh}} = \dfrac{\hbar c}{4\pi r_{\mathrm{S}}} \qquad T_{\mathrm{bh}}\cdot r_{\mathrm{a}} = \dfrac{\hbar c}{4\pi}\sqrt{\dfrac{27}{4}}$

$$\alpha_{bh} = \frac{T^4 r^4 \pi^3}{60\hbar^4 c^4} = \frac{1}{4^4 60\,\pi}\frac{27^2}{4^2} = \frac{27^2}{4^6 60\,\pi} = \frac{1}{1059.1}$$

If we turn all emission to infinity off $\alpha_{bh} = \dfrac{27^2}{4^6\,30\,\pi} = \dfrac{1}{529.5} \qquad q = 0.815\times 10^{-19}\ \mathrm{C} = 0.509\,e$

See Lestone arXiv:physics/0703151v1 (2007)

Calculating the fine structure constant for my imaginary particles



$$\Gamma = \frac{1}{2\pi}\int_0^\infty \sum_{\text{helicity}} \sum_{L=0}^{\infty} (2L+1) T_L(\varepsilon) \exp(-\varepsilon / T) d\varepsilon \qquad R = \frac{\Gamma}{\hbar}$$

$$P_{A\to\infty} = \frac{1}{\pi\hbar}\int_0^\infty \varepsilon T_{L=0}(\varepsilon) \exp(-\varepsilon / T_{\mathrm{p}})\, d\varepsilon.$$

For my particles this is not allowed

$$P_{A\to B} = \frac{1}{\pi\hbar}\int_0^\infty \varepsilon \frac{T_{L=0}(\varepsilon, d) \exp(-\varepsilon / T_{\mathrm{p}})}{\exp(\varepsilon / T_{\mathrm{ex}}) - 1} \frac{\sigma_a(\varepsilon, d)}{4\pi d^2} d\varepsilon \qquad \sigma_a(\varepsilon, d) = \pi \lambda\!\!\!^{-}{}^2 T_{L=0} = \pi \lambda\!\!\!^{-}{}^2 \mathrm{erf}^2\left(\frac{d}{\lambda\!\!\!^{-}\sqrt{2}}\right) \qquad \lambda\!\!\!^{-} = \frac{\hbar c}{\varepsilon}$$

If $T_{\mathrm{p}} >> T_{\mathrm{ex}}$

$$F = \frac{2}{\pi\hbar c}\int_0^\infty \frac{\varepsilon T_{L=0}(\varepsilon, d)}{(\exp(\varepsilon / T_{\mathrm{ex}}) - 1)} \frac{T_{L=0}(\varepsilon, d)\, \pi \lambda\!\!\!^{-}{}^2}{4\pi d^2} d\varepsilon = \frac{\hbar c}{2\pi d^2}\int_0^\infty \frac{(T_{L=0}(\varepsilon, d))^2}{\varepsilon (\exp(\varepsilon / T_{\mathrm{ex}}) - 1)} d\varepsilon.$$

$$\alpha = \frac{1}{2\pi}\int_0^\infty \frac{(T_{L=0}(\varepsilon, d))^2}{\varepsilon (\exp(\varepsilon / T_{\mathrm{ex}}) - 1)} d\varepsilon = \infty \quad \text{if } T_{L=0}(\varepsilon, d) = 1.$$

Calculating the fine structure constant continued

$$\alpha = \frac{1}{2\pi}\int_0^\infty \frac{(T_{L=0}(\varepsilon))^2}{\varepsilon\,(\exp(\varepsilon/T_{\mathrm{ex}})-1)}\,d\varepsilon = \infty \quad \text{if } T_{L=0}(\varepsilon)=1.$$

The origin of the divergence is the lowest energy photons where $\lambdabar > d$ and the transmission coefficients need to be modified to lower values to correct for near-field effects. This is the reason for my

$$T_{L=0}(\lambdabar, d) = \mathrm{erf}^2\left(\frac{d}{\lambdabar\sqrt{2}}\right).$$

$$\frac{d}{\lambdabar\sqrt{2}} = \frac{\varepsilon d}{\hbar c\sqrt{2}} = \frac{\varepsilon 2d}{\hbar c 2\sqrt{2}} = \frac{\varepsilon}{T_{\mathrm{ex}} 2\sqrt{2}}$$

$$\alpha = \frac{1}{2\pi}\int_0^\infty \frac{\mathrm{erf}^4(\varepsilon/2^{3/2})}{\varepsilon\,(\exp(\varepsilon)-1)}\,d\varepsilon \qquad \alpha^{-1} = 138.9 \qquad q = 1.591\times 10^{-19}\ \mathrm{C}$$

If we assume QED-like corrections to the $T_{L=0}$, with $T_{L=0}(\lambdabar, d) = \mathrm{erf}^{2/(1+\eta(\alpha))}\left(\frac{d}{\lambdabar\sqrt{2}}\right)$ $\qquad \eta(\alpha) = \sum_n 4\pi\, c_n^2 \left(\frac{\alpha}{\pi}\right)^n$

where the C_n are the coefficient from the QED calculation of the magnetic momentum of the electron

$$\mu_e = 1 + c_1\left(\frac{\alpha}{\pi}\right) + c_2\left(\frac{\alpha}{\pi}\right)^2 + c_3\left(\frac{\alpha}{\pi}\right)^3 + c_4\left(\frac{\alpha}{\pi}\right)^4 + \ldots$$

c_1=0.5, c_2=–0.328478965579… , c_3=1.181241456587…

$$\alpha = \frac{1}{2\pi}\int_0^\infty \frac{\mathrm{erf}^{4/(1+\eta(\alpha))}(\varepsilon/2^{3/2})}{\varepsilon\,(\exp(\varepsilon)-1)}\,d\varepsilon \qquad \alpha^{-1} = 137.035891 \qquad q = 1.602177\times 10^{-19}\ \mathrm{C}$$

See Lestone, Vixra:1602.0013

Properties used to calculate the fine structure constant for my imaginary particles

(1) My particles have a very high temperature.
(2) Despite having a high temperature my imaginary particles can not change their rest mass upon the emission of electromagnetic energy. Using known physics my imaginary particles (if isolated) can not emit any “real” photons.
(3) However, I consider the possibility that my imaginary particles can emit and absorb unphysical *L*=0 “virtual” photons via the time-energy uncertainty principle.
(4) The emission and absorption is controlled by statistical arguments involving their assumed “classical” temperature and possibly other effective temperatures.
(5) The emission and absorption between pairs, to 0th order, is controlled by a cross section $\sigma_a(\lambdabar, d) = \mathrm{erf}^2(d/(\lambdabar\sqrt{2}))\pi\lambdabar^2$.
(6) The characteristic energy of the photons exchanged between particle pairs is given by $T_{ex}=\hbar c/(2d)$ and is assumed to define a Planckian exchange temperature.
(7) QED-like corrections based on the anomalous magnetic moment of the electron are assumed.

The assumptions in black are assumed without explanation.
The assumptions in red are partially justifiable.
Remember the emission of “real” *L*=0 photons from classical black holes is not allowed.

The properties 1-7 define a universal change of 1.60×10^{-19} C. Of course the reverse can not be said. i.e. the apparent match to the known fine structure constant can not be used to claim leptons have the listed properties.

All seven properties can be “understood” via the concept of quantum micro black holes.

(5) The emission and absorption between pairs, to 0th order, is controlled by a cross section $\sigma_a(\lambdabar, d) = \mathrm{erf}^2(d/(\lambdabar\sqrt{2}))\pi\lambdabar^2$.

- Unphysical L=0 photon emission and absorption cross section for black holes is $\sigma_a(\lambdabar) = \pi\lambdabar^2$. Crispino *et al*. (PRD **75** 2007)
- This can be calculated assuming spherical symmetry, and thus plane waves coming in from or going out to infinity.
- For photon wavelengths much smaller than the distance between two black holes, the black holes behave like classical emitters and absorbers with effective radii = $\lambdabar$.
- Simple arguments suggest there must be near-field corrections and $\sigma_a(\lambdabar, d) \le \pi\lambdabar^2$.

In fact, one might expect

$$\left.\begin{aligned} \sigma_a(\lambdabar, d) &= \pi\lambdabar^2, \quad 2\lambdabar \ll d. \\ &\sim 0.5\pi\lambdabar^2, \quad \lambdabar = d. \\ \text{and} \quad T_{L=0} &\ll 1 \,, \quad \lambdabar \gg d. \end{aligned}\right\}$$

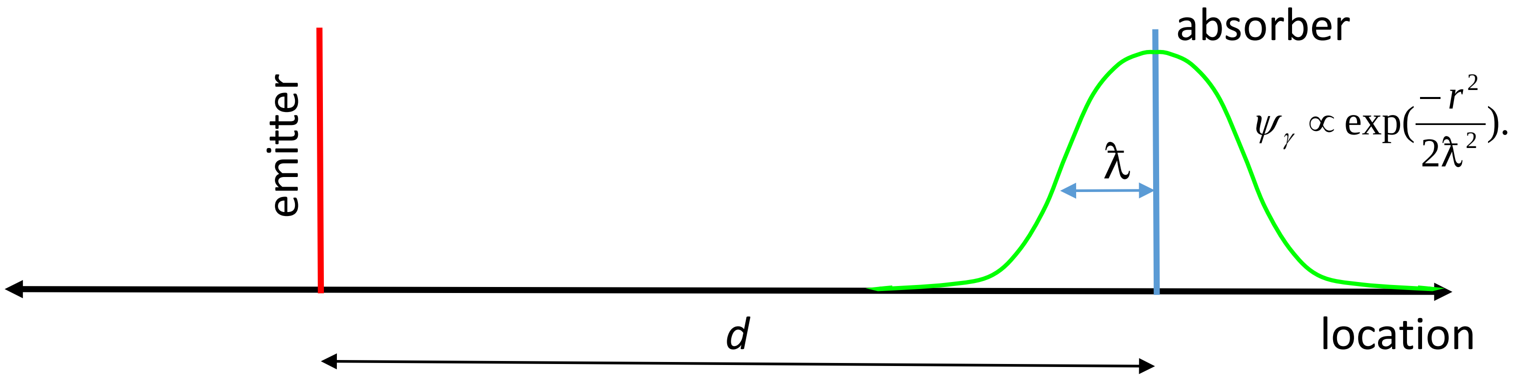
Similar arguments to Bethe's work in the 30's where QED integrals were simply cut off when $d \sim \lambdabar$.

One might imagine a wave function controlling the distribution of virtual photons around my particles.
If so, what would the distribution be?

$$\psi_\gamma \propto \exp\left(\frac{-r^2}{2\lambdabar^2}\right)$$

An educated guess at the near-field correction (with no QED corrections)

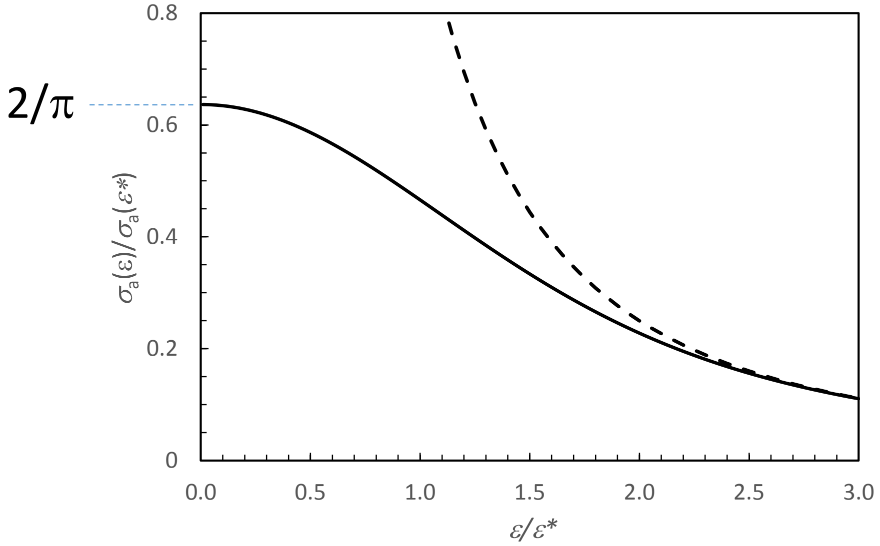
Emitters and absorbers separated by $d<\bar{\lambda}$ can not behave independently



I assume the ratio of a near-field to far-field interaction length scale is $\frac{r_{\mathrm{n}}}{r_{\mathrm{f}}} = \frac{2}{\bar{\lambda}\sqrt{2\pi}} \int_0^d \exp(\frac{-r^2}{2\bar{\lambda}^2})dr.$

The corresponding near-field modified transmission coefficients are $T_{L=0}(\bar{\lambda}, d) = \mathrm{erf}^2(\frac{d}{\bar{\lambda}\sqrt{2}}).$

$$\sigma_a(\bar{\lambda}, d) = \mathrm{erf}^2(\frac{d}{\bar{\lambda}\sqrt{2}})\pi\bar{\lambda}^2.$$



Despite the "educated guess" the real reason for this assumption is it leads to a result close to the answer I am seeking.

The energy axis is in units of $\varepsilon^*=\hbar c/d$. At $\varepsilon/\varepsilon^*=1$ and 2, the separation between emitter and absorber are 1 and 2 reduced wavelengths of the transferring photon, respectively.

(6) The characteristic energy of the photons exchanged between particle pairs is given by T_{ex}=ħc/(2d) and is assumed to define a Planckian exchange temperature.

- The characteristic energy of the virtual photons exchanged across a distance *d* is given by the time-energy uncertainty principle $T_{ex} \cdot \tau = \hbar / 2$ with $\tau = d / c$.
- Perhaps one could invoke a sharp cutoff with all virtual exchanges assigned a "jumping" probability of 1 if $\varepsilon < T_{ex}$ and 0 otherwise. However, sharp cutoffs are not intuitively pleasing.
- Inspired by the notion that statistical concepts apply, perhaps we should assume a "jumping" probability of $\exp(-\varepsilon / T_{ex})$ and use the characteristic energy as an effective exchange temperature.
- In the classical emission from a black body the classical temperature term $\exp(-\varepsilon / T_{ex})$ must be replaced with the Planckian factor $1/(\exp(\varepsilon / T_{ex}) - 1)$ to get the right answer. Perhaps this is the only explanation required but I doubt it.
- It has been shown that black holes are stimulated to emit a photon with a probability of $\exp(-\varepsilon / T_{ex})$ for each absorption from infinity (Bekenstein and Meisels, PRD **15** 1977). If this stimulated emission is reabsorbed by the partner particle at a distance *d*, then this will cause a stimulated emission "perhaps" back to the other, and so forth. If this is assumed then the effective exchange "jump" probability becomes

$$f = \exp(-\varepsilon / T_{ex}) + \exp^2(-\varepsilon / T_{ex}) + \exp^3(-\varepsilon / T_{ex}) + \ldots$$

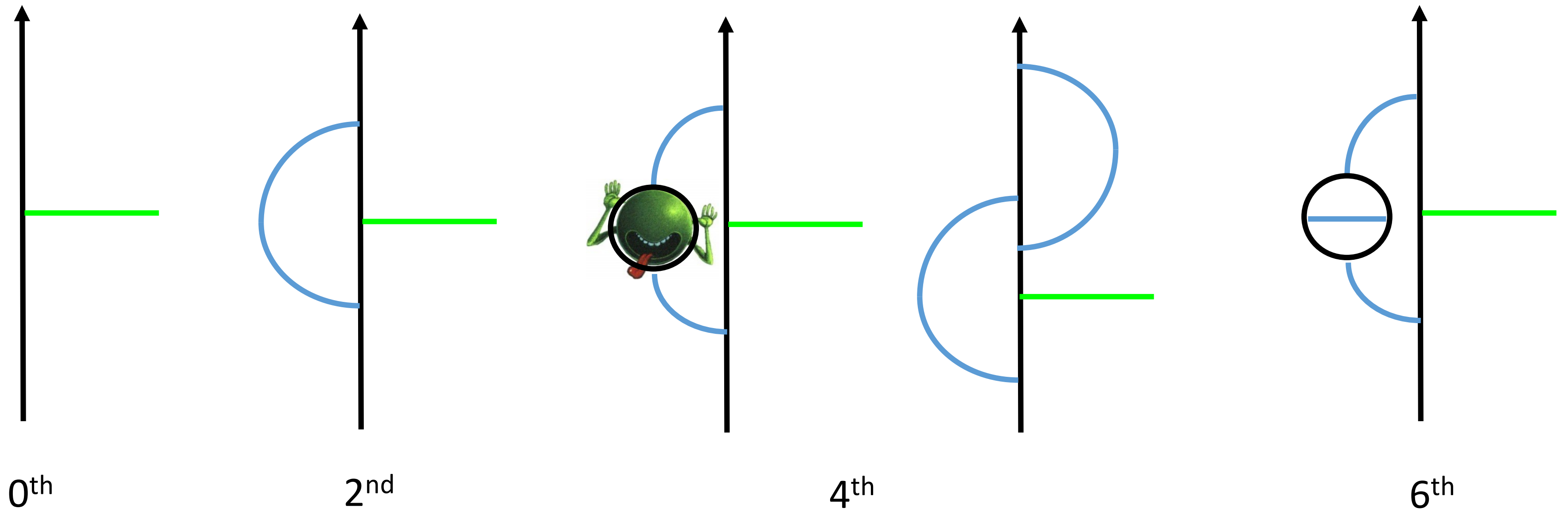
$$f = \frac{\exp(-\varepsilon / T_{ex})}{1 - \exp(-\varepsilon / T_{ex})} = \frac{1}{\exp(\varepsilon / T_{ex}) - 1}$$

The real reason for using this factor is it leads to a result close to the answer I am seeking.

(7) QED-like corrections based on the anomalous magnetic moment of the electron are assumed.

QED calculations of the anomalous magnetic moment of the electron

$a=(g-2)/2$ Feynman diagrams



$$a=\frac{g-2}{2}=\sum_{n=1}^{\infty}A_1^{(2n)}(\frac{\alpha}{\pi})^n=c_1(\frac{\alpha}{\pi})+c_2(\frac{\alpha}{\pi})^2+c_3(\frac{\alpha}{\pi})^3+c_4(\frac{\alpha}{\pi})^4+\ldots$$

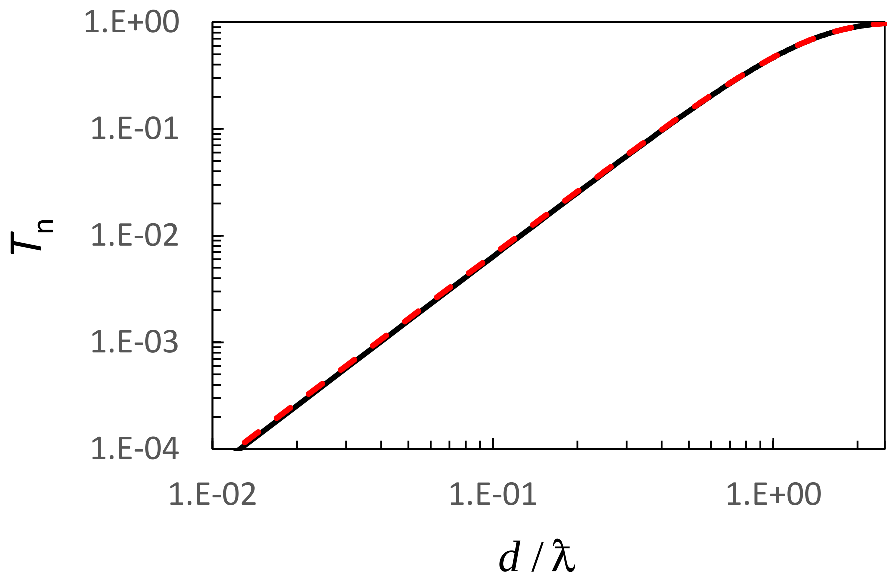
c_1=0.5 (1948), c_2=–0.328478965579... (1957), c_3=1.181241456587... (1996)

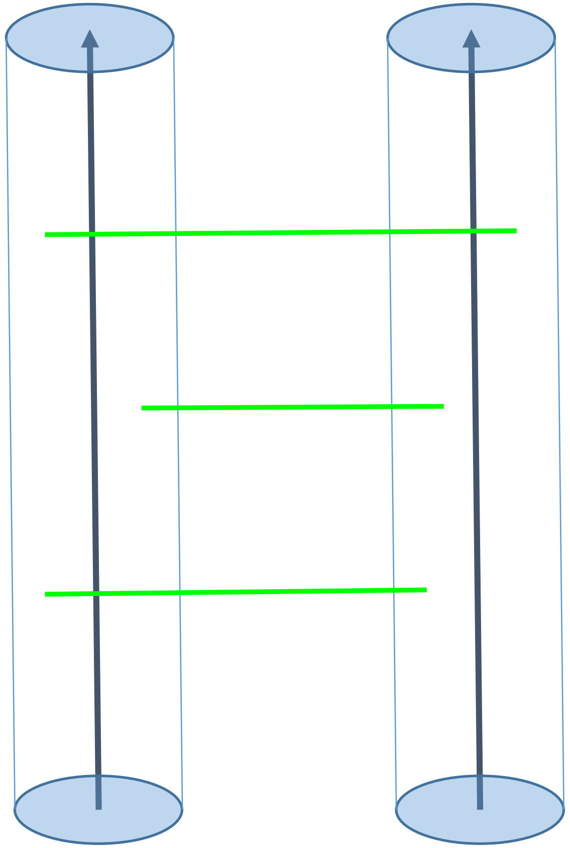
$$a=\frac{1}{2\times 137.036\pi}-\frac{0.328478965579\ldots}{(137.036\pi)^2}+\frac{1.181241456587\ldots}{(137.036\pi)^3}$$

a_6 =0.00115965222434

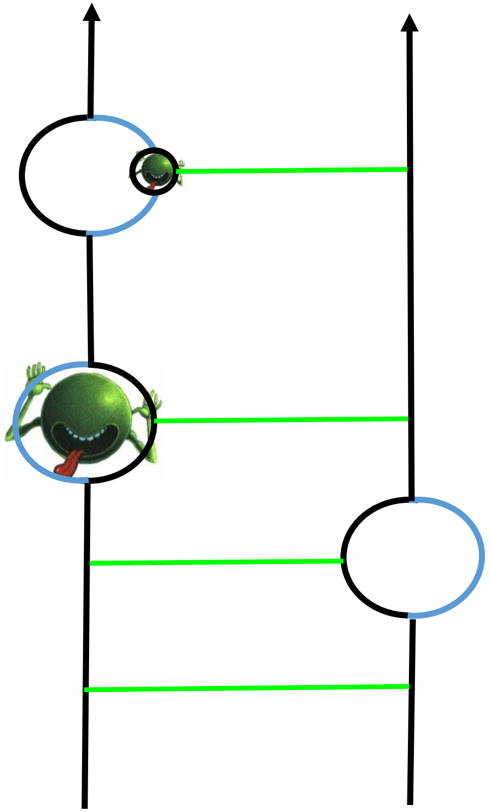
a_{exp} =0.00115965218

Speculative QED corrections to the near-field corrections





$$T_L = \mathrm{erf}^2\left(\frac{d}{ƛ\sqrt{2}}\right)$$



$$T_L = \mathrm{erf}^{2/(1+\eta(\alpha))}\left(\frac{d}{ƛ\sqrt{2}}\right)$$

I believe the QED corrections to the near-field cross sections will be controlled by terms similar to the QED correction to the magnetic moment.

Speculative QED corrections continued

$$T_L = \mathrm{erf}^{\,2/(1+\eta(\alpha))}\left(\frac{d}{\lambda\sqrt{2}}\right)$$ with positive $\eta(\alpha)$.

$$a = \frac{g-2}{2} = \sum_{n=1}^{\infty} A_1^{(2n)}\left(\frac{\alpha}{\pi}\right)^n = c_1\left(\frac{\alpha}{\pi}\right) + c_2\left(\frac{\alpha}{\pi}\right)^2 + c_3\left(\frac{\alpha}{\pi}\right)^3 + c_4\left(\frac{\alpha}{\pi}\right)^4 + \ldots \qquad = 0.00116$$

is related to the relative path lengths in space-time where the lepton location is fuzzy due to a surrounding cloud of virtual photons and particle-antiparticle pairs.

Perhaps for the QED correction to the near-field correction, we need a ratio of a QED-corrected fuzzy effective surface area to a corresponding sharp surface area. This suggests a change in symmetry from “length” in the case of the anomalous magnetic moment to “surface area” for the case of the near-field cross sections.

Inspired by these speculative arguments I assume $\eta(\alpha) = \sum_{n=1}^{\infty} 4\pi c_n^2 \left(\frac{\alpha}{\pi}\right)^n$.

The real reason for using this assumed QED-like correction is it leads to a result close to the answer I am seeking.

This recipe also gives a “good” semi-classical interpretation of the anomalous magnetic moment of my particles that differs from the electron by ~1 part in 10^6 (later if time permits).

Possible higher order correction to my fine structure constant calculation

$$\alpha = \frac{1}{2\pi}\int_0^\infty \frac{\mathrm{erf}^4(\varepsilon/2^{3/2})}{\varepsilon(\exp(\varepsilon)-1)}\,d\varepsilon \quad\rightarrow\quad \alpha^{-1} = 138.9098824$$

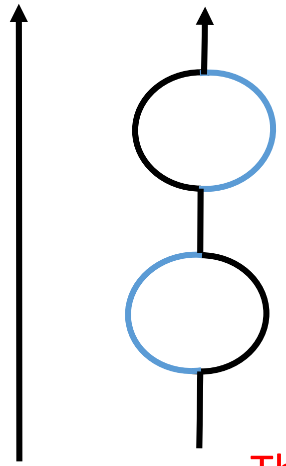
$$q = 1.591\times10^{-19}\ \mathrm{C}$$

$$\left.\begin{aligned}\alpha &= \frac{1}{2\pi}\int_0^\infty \frac{\mathrm{erf}^{4/(1+\eta(\alpha))}(\varepsilon/2^{3/2})}{\varepsilon(\exp(\varepsilon)-1)}\,d\varepsilon \\ \eta(\alpha) &= 4\pi\left((0.5)^2\frac{\alpha}{\pi} + 0.3284789...^2\left(\frac{\alpha}{\pi}\right)^2 + 1.1812456587...^2\left(\frac{\alpha}{\pi}\right)^3 + ...\right) \\ &= \alpha + 0.137380549...\alpha^2 + 0.565510531...\alpha^3 + ...\end{aligned}\right\}$$

$\alpha^{-1} = 137.035891$ — out by 1 part in 10^6

$q = 1.60217725\times10^{-19}$ C — out by 1 part in 2×10^6

If my QED correction is on the right path, there will be additional higher order QED corrections.
The next "obvious" correction is due to the use of the standard (g–2)/2 correction which assumes no other nearby charges.



suppressed slightly

enhanced slightly

This will slightly decrease the effect of my first QED correction

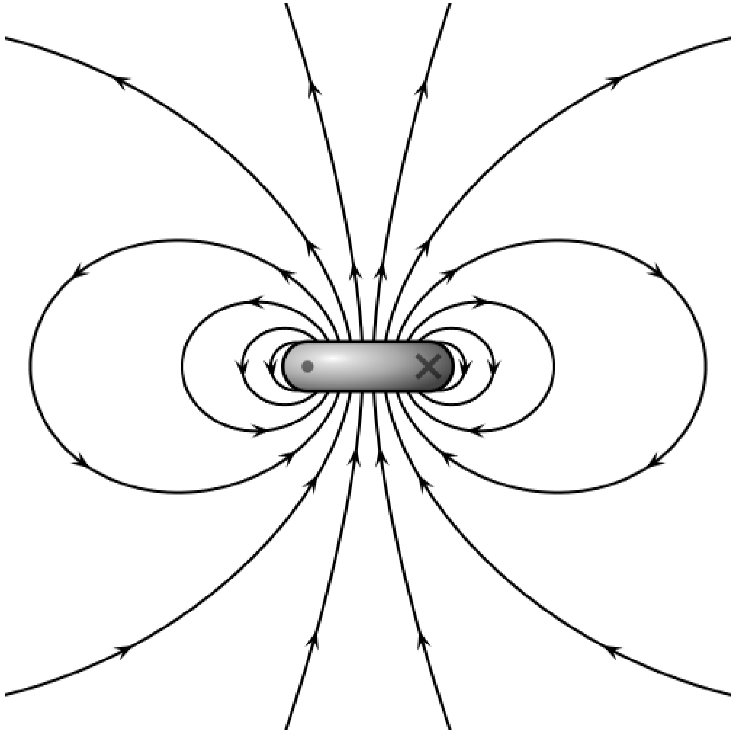
138.9098824 → 137.035891

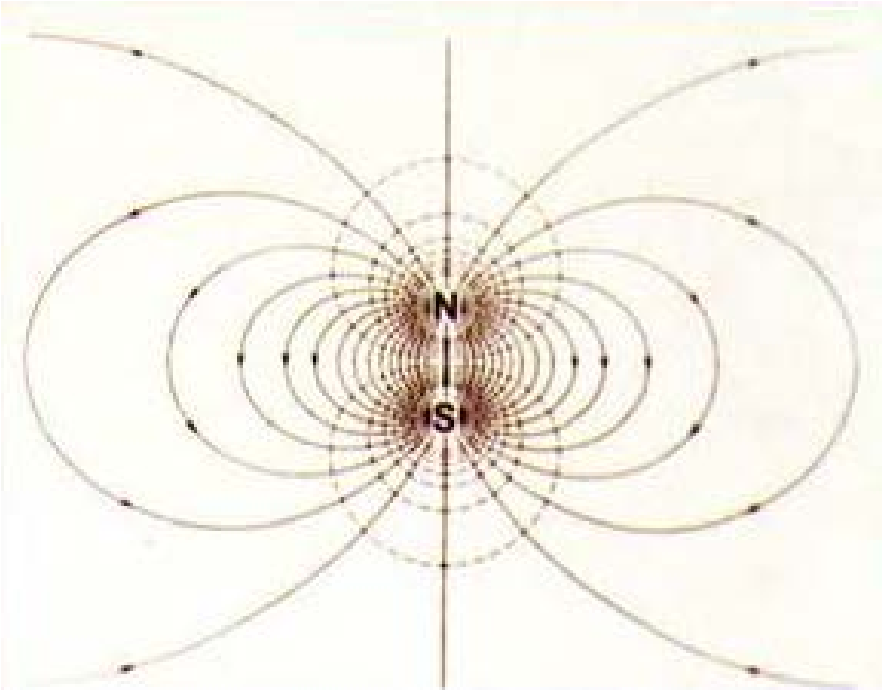
I would "like" it if my QED correction was decreased by 1 part in 6×10^5

The real reason for hoping this is, perhaps it will lead to a result closer to the answer I am seeking.

The magnetic moment of the electron is $\mu_S = \frac{-g_S \mu_{\mathrm{B}}}{2}$ where $\mu_{\mathrm{B}} = \frac{e\hbar}{2m_e}$.

All electrons behave like little bar magnets with total spin angular momentum of $s=\hbar/2$





The Dirac equation gives g_S=2, however the experimental value is g_S=2.00231930436146(28).

$$a = \frac{g-2}{2} = 0.00115965218073(28) \qquad \frac{\alpha}{2\pi} \sim \frac{1}{137 \cdot 2\pi} = 0.001162$$

$$\mu_e = 1.00115965\ \mu_{\mathrm{B}}$$

Calculating the magnetic moment of my imaginary particles

(8) The magnetic moment of my “naked” particles in 1 μ_B (like leptons). When in a state after virtual photon emission but before the reabsorption of the same virtual photon, the my-particle-photon state generates an additional 1 μ_B of magnetism giving a total value of 2 μ_B. To generate the additional magnetic moment of 1 μ_B my particles are assumed to travel on an arc between emission and self-absorption of virtual photons. If the fraction of time spent in this rare intermediate state is f then the magnetic moment of the “dressed” particle is $\mu_p=(1\times(1-f)+2f)\ \mu_B=(1+f)\ \mu_B$.

(9) For the case of self-absorption the emission process is assumed to not know the distance to the absorption location and the near-field corrected cross section is not used. For reabsorption, the emission location is known and the distance dependent near-field transition coefficient is used, with the far-field cross section scaled by α.

(10) The self-absorption process in modified by a scaling factor $\exp(-\varepsilon/T_{sa})$ where ε is the energy of the virtual photon and T_{sa} is a self-absorption temperature and is equal to $mc^2/2$.

$$v=\frac{\varepsilon}{mc},\qquad \tau=\frac{\hbar}{2\varepsilon},\qquad x_c=\frac{\varepsilon}{mc}\frac{\hbar}{2\varepsilon}=\frac{\hbar c}{2mc^2}=\frac{r_C}{2}$$

$$f=\frac{2}{r_C T_{sa}}\int_0^\infty\int_0^\infty \frac{\exp(-\frac{2x}{r_C})\exp(-\frac{\varepsilon}{T_{sa}})\mathrm{erf}^{2/(1+\eta(\alpha))}(\sqrt{1-\cos(\theta)})\,\alpha\pi\bar{\lambda}^2}{4\pi\bar{\lambda}^2\,2(1-\cos(\theta))}\,d\theta\,d\varepsilon$$

$$\mu_p=1+\frac{\alpha}{2}\int_0^\infty\int_0^\infty\frac{\exp(-2x)\exp(-2\varepsilon)\mathrm{erf}^{2/(1+\eta(\alpha))}(x\varepsilon)}{(1-\cos(x\varepsilon))}\,dx\,d\varepsilon=1.001161\ \mu_B$$

$$\sim 1.00111\ \ \mu_B\ \text{(with no QED correction)}$$

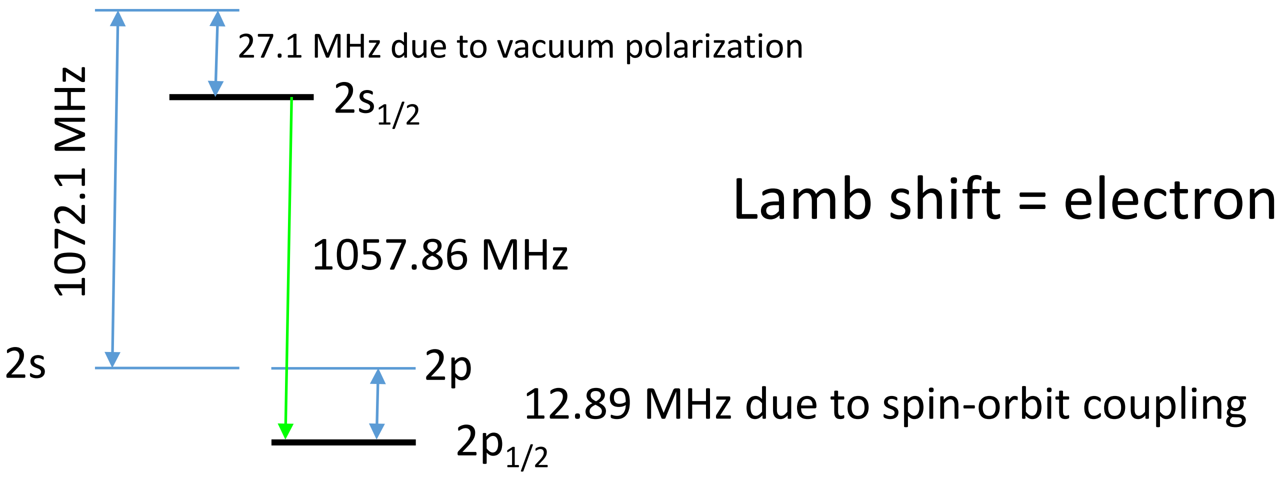
My imaginary particles have a magnetic moment that differs from that of an electron by ~1 part in 10^6. There are higher order corrections. See Lestone LA-UR-16-20131 (2016). The symmetry between length and energy in the above equation is obtained by the choice of T_{sa}=0.5 (mc^2)

If the recoiling particles are instead assumed to recoil in a straight line (but then how would the extra moment be generated?)

$$\mu_p=1+\alpha\int_0^\infty\int_0^\infty\frac{\exp(-2x)\exp(-2\varepsilon)\mathrm{erf}^{2/(1+\eta(\alpha))}(x\varepsilon)}{x^2\varepsilon^2}\,dx\,d\varepsilon=1.001156\ \mu_B$$

The Lamb shift (1057.86 Hz)

Hydrogen 2s-2p states

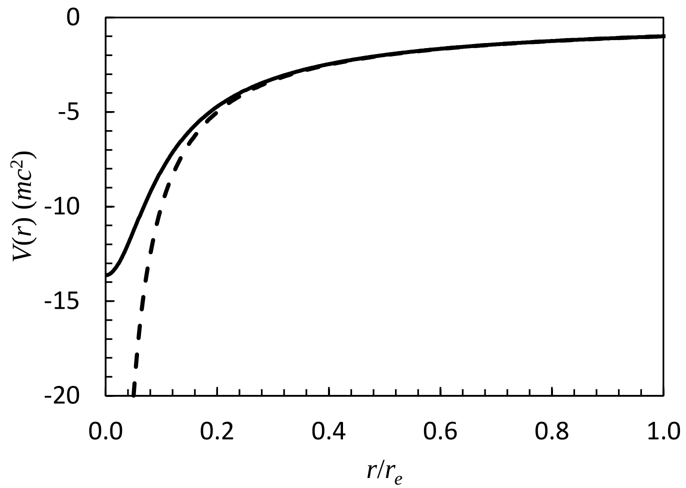


Lamb shift = electron fuzziness correction to the 2s level – 14 MHz

(11) There is an equivalence between the fuzziness generated by the virtual photon emission by my particles and the fuzziness generated by the interaction of a charged lepton (of the same mass) in the electromagnetic vacuum.
(12) The potential between a heavy particle and my fuzzy imaginary particles at a distance *r* is modified away from a pure 1/*r* potential via the fraction of my particles' fuzziness that lies within a sphere of radius *r*.

$$\Delta E_{20} = \frac{\alpha^4}{2}\int_0^\infty r(1-\alpha r/2)^2 \exp(-\alpha r)\left(2\alpha^{1/4}\int_{3\alpha/2}^\infty \mathrm{erf}\left(\frac{r}{2}\sqrt{\frac{\pi\varepsilon}{\alpha}}\right)\exp(-2\alpha^{1/4}\varepsilon)\frac{d\varepsilon}{\exp(-3\alpha^{5/4})} - 1\right)dr \quad (mc^2) = 1070\ \mathrm{Mhz}$$

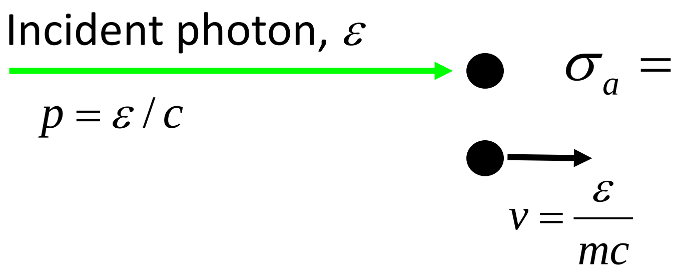
The Lamb shift for my imaginary particles (with the same mass as the electron) bound to a heavy oppositely charged particle is 1056 MHz. This differs by 0.2% from the hydrogen Lamb shift.



See Lestone LA-UR-16-20131 (2016)

Compton scattering by my imaginary particles

(13) For a "real" incident photon the far-field cross section is scaled by α.
(14) When accelerated my imaginary particles radiate as though they are charged leptons.



$$\sigma_a = \alpha\pi(\hbar c / \varepsilon)^2$$

Of course, this photon absorption violates conservation of energy and is not allowed.

In the non-relativistic limit, $\varepsilon << mc^2$, the violation in conservation of energy associated with the absorption is ε, and thus can not exist for a time period longer $\tau = \hbar/(2\varepsilon)$.

If the velocity v is thought to be obtained over this time scale then the acceleration associated with the absorption is given by $a = 2\varepsilon^2/(\hbar mc)$.

The power of emission from an accelerating classical charge in the non-relativistic limit is given by $P = \dfrac{2}{3}\dfrac{e^2}{4\pi\varepsilon_0}\dfrac{a^2}{c^3} = \dfrac{2\alpha\hbar c a^2}{3c^3}$.

So if the "unphysical" absorption is allowed then the recoiling lepton can reradiate an amount of energy

$$E = \frac{2\alpha\hbar c a^2 \tau}{3c^3} = \frac{2\alpha\hbar c}{3c^3}\frac{4\varepsilon^4}{(\hbar mc)^2}\frac{\hbar}{2\varepsilon} = \frac{4\alpha}{3}\frac{\varepsilon^3}{(mc^2)^2}.$$

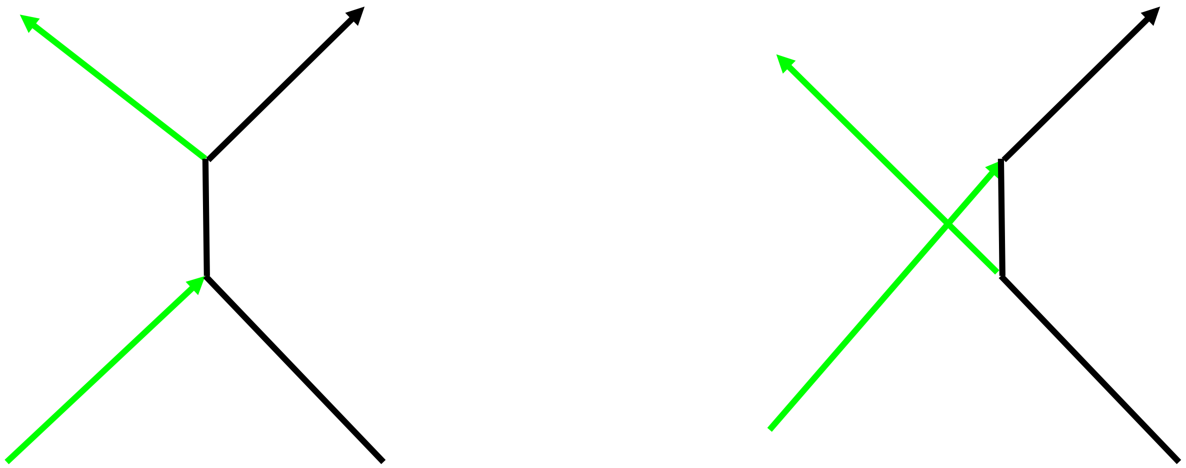
If during the time τ the recoiling lepton can re-emit the photon of energy ε, then conservation of energy can be re-established and thus the absorption can be allowed. If the radiation during the recoil phase is confined to a photon of energy ε then the probability of emitting the conservation-of-energy re-establishing photon is given by $\mathrm{P} = \dfrac{4\alpha}{3}\dfrac{\varepsilon^2}{(mc^2)^2}$.

$$\sigma = \sigma_a \mathrm{P} = \frac{\alpha\pi(\hbar c)^2}{\varepsilon^2}\frac{4\alpha}{3}\frac{\varepsilon^2}{(mc^2)^2} = \frac{4\pi}{3}\left(\frac{\alpha\hbar c}{mc^2}\right)^2$$

Compton scattering continued

$$\sigma = \sigma_a \mathrm{P} = \frac{\alpha\pi(\hbar c)^2}{\varepsilon^2}\frac{4\alpha}{3}\frac{\varepsilon^2}{(mc^2)^2} = \frac{4\pi}{3}\left(\frac{\alpha\hbar c}{mc^2}\right)^2$$

Feynman diagrams for Compton scattering (and pair annihilation and creation)



$$\sigma_{\mathrm{C}} = 2\times\frac{4\pi}{3}\left(\frac{\alpha\hbar c}{mc^2}\right)^2 = \frac{8\pi}{3}r^2 \qquad r = \frac{\alpha\hbar c}{mc^2}$$

Summary

- Relatively simple intuitive (at least to me) recipes can be used to explain several key QED results.
- These are simple enough that they can be explained to an undergraduate audience.
- If electromagnetism is caused by the virtual exchange of L=0 photons between pairs of particles with the properties discussed, the corresponding coupling constant can be calculated. By invoking near-field corrections, QED corrections to the near-field corrections, I calculate α^{-1}=137.0359 and q=1.602177$\times$10^{-19} C.
- The reason for fractional charged quarks is not considered.
- Anomalous magnetic moment of the leptons can be obtained via a recipe assuming a dance of the virtual photon emission and self-absorption causing the lepton to generate an additional 1 μ_B for $\alpha/(2\pi)$ of the time. This requires an effective self-absorption temperature of $mc^2/2$. My recipe gives μ_p=1.001161 μ_B, out by ~1 part in 10^6 from the corresponding value for the electron.
- Lamb shift: Invoking a particle fuzziness associated with the self-absorption temperature of $mc^2/2$ leads to a calculated Lamb shift of 1056 MHz (experimental value is 1057.86 MHz).
- Compton scattering can be thought of as a three step process:
  (1) An absorption that violates conservation of energy; (2) the corresponding NOT allowed recoil; and (3) the emission of an energy conservation re-establishing photon associated with the acceleration during the recoil; and finally a factor of two associated with reversing the order of the absorption and emission.
- The calculations presented here suggest that the possibility that the charged leptons have properties that resemble quantum micro black holes and that electromagnetism is generated by the exchange of Hawking radiation, should be considered further.

Backup slides

Abstract

Quantum electrodynamics is complex and its associated mathematics can appear overwhelming for those not trained in this field. Semi-classical approaches are used to obtain a more intuitive physical feel for several QED processes including electrostatics, Compton scattering, and pair annihilation. Treating leptons as quantum micro black holes that emit and reabsorb virtual Hawking radiation leads to relatively simple, but speculative, recipes for the calculation of the anomalous magnetic moment of the electron, and the Lamb shift. These intuitive arguments require no complex relativity theory or complex quantum mechanics, and lead to a possible answer to the question of the nature of charge. These recipes lead to a calculated charge of the electron of q=1.602177×10^{-19} C with a corresponding calculated inverse fine structure constant of α^{-1}=137.036. These calculations suggest electromagnetism is generated by the exchange of virtual Hawking radiation between elementary particles with properties that resemble black holes.

QED-like semi-classical interpretation of electrostatic repulsion between two leptons

$$F = \frac{\alpha \hbar c}{d^2} \qquad \alpha = \frac{e^2}{4\pi\varepsilon_0 \hbar c}$$

Imagine, for simplicity, that the virtual photons being exchanged between two leptons are all of the same energy, ε, with a wavelength << *d*, and that they follow the rules of “real” photons.

$$\varepsilon \cdot \tau = \hbar / 2 \qquad \tau^{-1} = \frac{2\varepsilon}{\hbar}$$

$$F = \left(\frac{2\varepsilon}{\hbar}\right) \times \left(\frac{2\varepsilon}{c}\right) \times \left(\frac{\alpha\pi(\hbar c/\varepsilon)^2}{4\pi d^2}\right) \qquad \sigma_a = \alpha\pi(\hbar c/\varepsilon)^2 = \alpha\pi\lambda\!\!\!^{-2}$$

In support of (13).

Probability that a “virtual” emission is turned into an exchange via the absorption of the “virtual” photon by the other lepton

Rate of attempted “virtual” photon emissions from each lepton

Momentum transfer associated with the two way exchange of photons

Pair annihilation of my imaginary particles

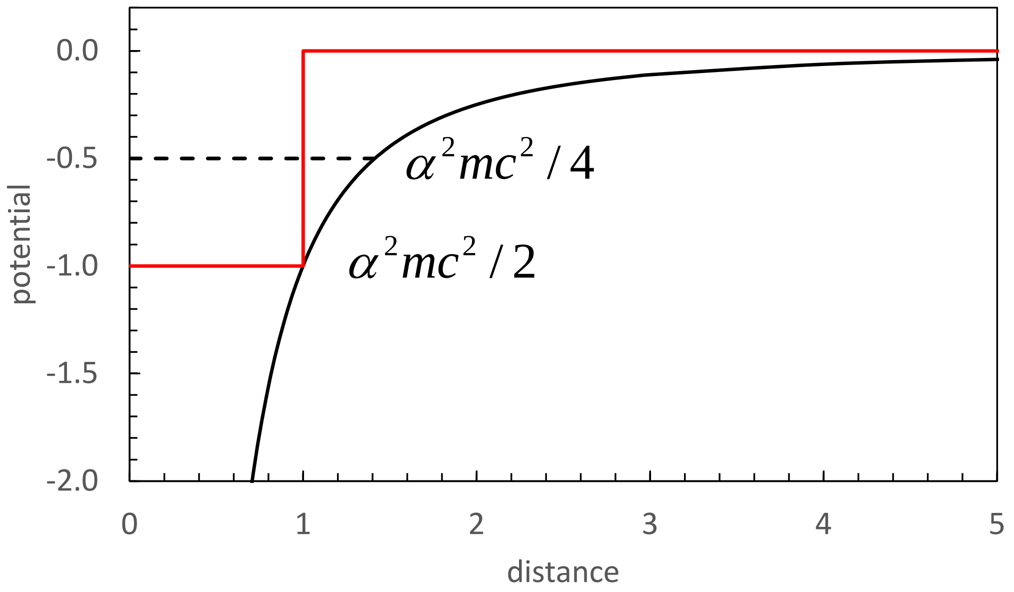
Incident positron

$p = mv$

$$\sigma_i = \pi \lambdabar^2 \qquad \lambdabar = \frac{\hbar}{p} = \frac{\hbar}{mv} = \frac{\hbar c}{mc^2}\frac{c}{v}$$

Cross section for a Coulomb interaction
$$\sigma_i = \pi \lambdabar^2 = \pi\left(\frac{\hbar c}{mc^2}\right)^2\left(\frac{c}{v}\right)^2 = \pi\, r_{\mathrm{C}}^2\left(\frac{c}{v}\right)^2$$

Including the Coulomb potential



Given a Coulomb interaction, the probability of forming a short lived positronium-like configuration is

$$\mathrm{P} = \sqrt{\frac{E}{V}} = \sqrt{\frac{1}{2}mv^2\frac{2}{\alpha^2 mc^2}} = \frac{v}{\alpha c}$$

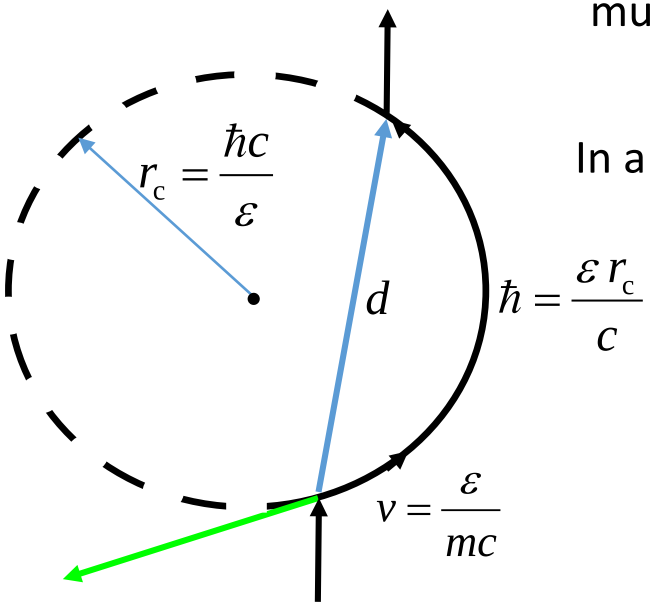
$$\sigma_{p\bar{p}} = \pi\left(\frac{c}{v}\right)^2\frac{v}{\alpha c} = \frac{\pi\, r_{\mathrm{C}}^2}{\alpha}\frac{c}{v}$$

Most positronium-like configurations will disintegrate. If each formation of a positronium-like configuration is associated with an annihilation probability of α^3, then

$$\sigma_A = \frac{\pi\, r_{\mathrm{C}}^2}{\alpha}\frac{c}{v}\alpha^3 = \pi\, r_e^2\frac{c}{v} \quad \text{and} \quad \frac{\sigma_A}{\sigma_s} = \frac{\alpha v}{c}$$

The α^3 probability was chosen to given the correct answer given the approximations chosen for the other steps.

Anomalous magnetic moment of my imaginary particles continued (in support of slide 19)



We assume the emission of a virtual photon of energy ε, which must be re-absorbed within a time scale $\tau = \hbar/(2\varepsilon)$ with $P(t) = \frac{\exp(-t/\tau)}{\tau}$.

In a time τ the lepton will travel a distance $s \sim \frac{\varepsilon}{mc}\frac{\hbar}{2\varepsilon} \sim \frac{\hbar c}{2mc^2} \sim r_C/2$ around the circular orbit.

The characteristic angle travelled around the circular orbit is $\theta_c = \frac{\varepsilon}{2mc^2}$.

Probability of self absorption (sa)

$$P_{sa} = \frac{\int_0^\infty \exp(-2x/r_C)\,\frac{\sigma_a(\varepsilon)}{4\pi d^2(\theta)}\,d\theta}{\int_0^\infty \exp(-2x/r_C)\,d\theta}$$

$$\sigma_a = \alpha\pi\lambdabar^2 \operatorname{erf}^{2/(1+\eta(\alpha))}\left(\frac{x}{\lambdabar\sqrt{2}}\right)$$

$$d^2(x) = 2\left(1-\cos\left(\frac{x\varepsilon}{\hbar c}\right)\right)\lambdabar^2$$

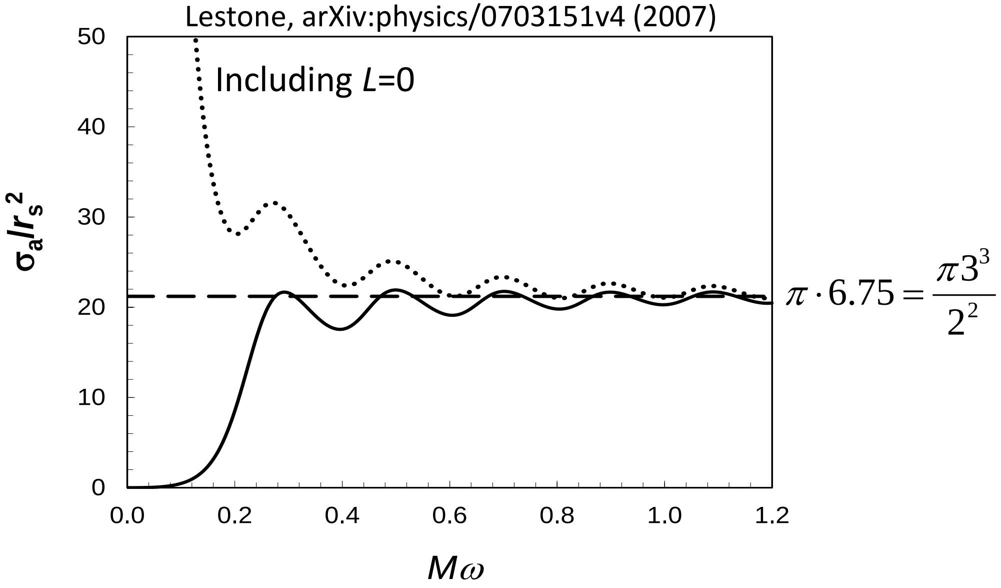
$$P_{sa} = \frac{\alpha}{2r_C T_{sa}}\int_0^\infty \exp(-2x/r_C)\,\frac{\hbar^2 c^2}{d^2(x)\varepsilon^2}\operatorname{erf}^{2/(1+\eta(\alpha))}\left(\frac{\varepsilon\, d(x)}{\hbar c\sqrt{2}}\right)\exp(-\varepsilon/T_{sa})\,dx\,d\varepsilon$$

$$P_{sa} = \frac{\alpha}{2}\int_0^\infty \frac{\exp(-2x)\exp(-2\varepsilon)\operatorname{erf}^{2/(1+\eta(\alpha))}\left(\sqrt{1-\cos(x\varepsilon)}\right)}{1-\cos(x\varepsilon)}\,dx\,d\varepsilon = 0.001161$$

Some Hawking radiation physics

$$\sigma_a = \sum_{L=1}^{\infty} \frac{(2L+1)\pi r_S^2}{4(M\omega)^2} T_L(M\omega) = \sum_{L=1}^{\infty} (2L+1)\pi \lambda\!\!\!^{-2} T_L(\varepsilon)$$

Crispino *et al*. (2007)



For a classical black hole with a continuum mass spectrum the emission of *L*=0 photons is unphysical.

I claim that for a quantum black hole in its ground state, *L*=0 photon emission is allowed and is analogous to virtual emission in QED. The difference is, for the black hole case the coupling constant is calculable.

$\sigma_a(L=0) = \pi \lambda\!\!\!^{-2}$ for absorption from and emission to infinity.

In support of (3) and (5).

For quantum micro black holes with discrete widely spaced states, the emission and absorption from and to infinity is not allowed because it will violate conservation of energy and momentum. However, via the time-energy uncertainty principle "virtual" emission and re-absorption by the same black hole, and the exchange of "virtual" photons between pairs of black holes is allowed. In support of (3).

For exchanges and re-absorptions with $\lambda\!\!\!^{-}$ << the distance between the emission and absorption locations, *d*, the appropriate cross section is the far-field value $\sigma_a(L=0) = \pi \lambda\!\!\!^{-2}$, and the black holes behave like classical spheres with radii $\lambda\!\!\!^{-}$. However, when $\lambda\!\!\!^{-}$ is about or larger than *d*, $\sigma_a(\lambda\!\!\!^{-}, d) < \pi \lambda\!\!\!^{-2}$.

Intrinsic fuzziness of leptons and black holes (in support of slide 11)

The emission and re-absorption will generate an intrinsic fuzziness of the lepton that can be described by a “wave-like” function $\Psi(r)$. The maximum “classically” allowed kinetic energy of a lepton, in an emission-re-absorption “dance” with a photon of energy ε, is $K = \varepsilon^2/(2mc^2)$. Assuming simple harmonic motion this corresponds to a classical maximum displacement amplitude of

$$r_m = \sqrt{\frac{2K}{m\omega^2}} = \sqrt{\frac{\varepsilon^2}{m^2c^2\omega^2}} = \frac{\hbar c}{mc^2} = r_C.$$

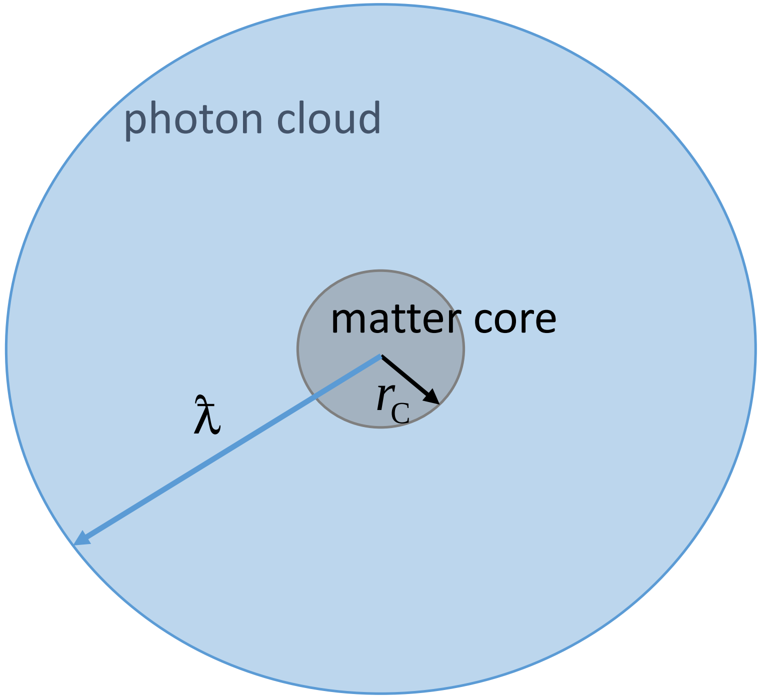
Translating from classical to quantum physics gives a wave-like function for the matter core of a lepton of

$$\psi \propto \exp\left(\frac{-r^2}{2r_C^2}\right)$$

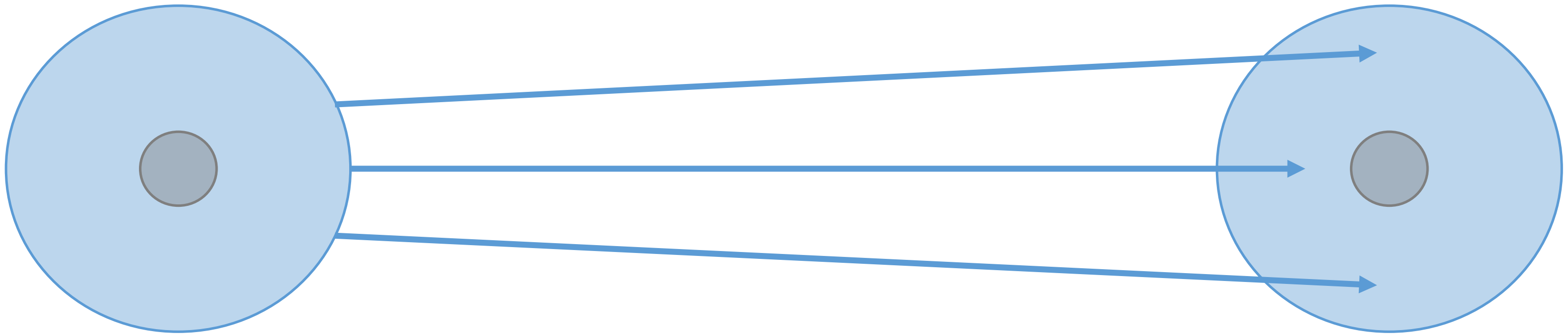
with a corresponding photon wave function of

$$\psi_\gamma \propto \exp\left(\frac{-r^2}{2\bar{\lambda}^2}\right).$$

Lepton model

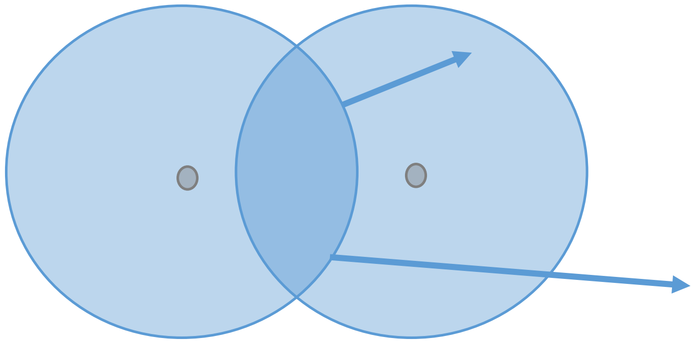


Near-field corrections (in support of slide 11)

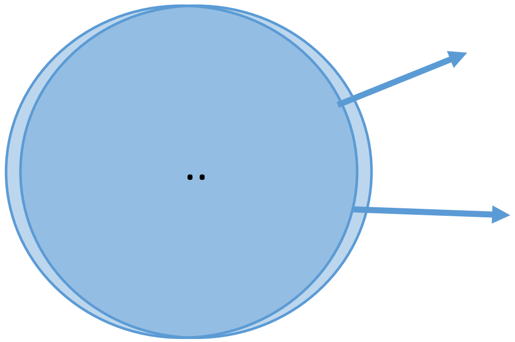


When $\lambdabar$ is << *d*, the leptons absorb photons as if they are spheres with a radius $\lambdabar$, with $T_{L=0}(\varepsilon)=1$

Imagine the distance between the two leptons remains the same but we consider photons with a larger $\lambdabar$ and rescale the drawing by the relative change of the photon wave lengths.



When $\lambdabar$ is $\sim d$, the effective absorption cross section will be $< \pi \lambdabar^2$ with $T_{L=0}(\varepsilon)<1$.



In the limit as $\varepsilon \to 0$ and $\lambdabar \to \infty >> d$, the effective absorption cross section will be $<< \pi \lambdabar^2$ with $T_{L=0}(\varepsilon) \to 0$.

Emitters and absorbers separated by $d<\lambdabar$ can not behave independently

Many others have tried to explain the fine structure constant

Equation guessing

$$\alpha = \Gamma^2 e^{-\pi^2/2} \qquad \Gamma = 1 + \frac{\alpha}{(2\pi)^0}\left(1 + \frac{\alpha}{(2\pi)^1}\left(1 + \frac{\alpha}{(2\pi)^2}\right)\left(1 + \frac{\alpha}{(2\pi)^3}\right)(1+\ldots)\right)$$

α^{-1}=137.03599911 Hans de Vries, www.chip-architect.com/news/2004_10_04_The_Electro_Magnetic_coupling.html

Single-electron physics based

Schonfeld and Wilde, Metrologia 45 (2008) 342-355, “Standing wave model of the macroscopically resting electron”

$$\alpha^{-1} = \pi^4\sqrt{2}\,\frac{m_m}{m_0}, \quad \frac{m_m}{m_0} \sim 1, \quad \alpha^{-1} = 137.7572576 \quad (1951)$$

$$\frac{m_0}{m_m} = 1 + \left(\frac{\alpha}{\sqrt{2}} f_v + 2\alpha^2\mu_{vm}^2\right) f_{\mathrm{H}}, \quad f_v = 1 - \frac{1}{2}c_1\left(\frac{\alpha}{\pi}\right) - \frac{37}{45}c_2\left(\frac{\alpha}{\pi}\right)^2 - \frac{27}{28}c_3\left(\frac{\alpha}{\pi}\right)^3 - \frac{141}{135}c_4\left(\frac{\alpha}{\pi}\right)^4 - \ldots$$

$$\mu_{vm} = 1 + c_1\left(\frac{\alpha}{\pi}\right) + c_2\left(\frac{\alpha}{\pi}\right)^2 + c_3\left(\frac{\alpha}{\pi}\right)^3 + c_4\left(\frac{\alpha}{\pi}\right)^4 + \ldots \quad , \quad f_{\mathrm{H}} = \frac{\sqrt{1+\alpha^2\mu_{vm}^2/2}}{1+2\alpha^2\mu_{vm}^2}$$

α^{-1}=137.035999252 (2008)